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Research was designed to evaluate the use of microcomputers for Navy training in a context that would permit the exploration of games for learning declarative information, in situ development of stand-alone computer-assisted instruction (CAI) systems, and techniques for developing automated tutors and student models. A data base of facts involving Soviet platforms and weapons systems was compiled and represented as a semantic network. The data base and a series of drill and practice games were implemented on a TERAK microcomputer and installed at the Fleet Combat Training

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Center, Pacific for tactical action officer training. Results of a formative evaluation of the training are described in this report.

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DEVELOPMENT OF A COMPUTER-BASED TACTICAL TRAINING SYSTEM

NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER, SAN DIEGO, CALIFORNIA

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NPRDC Special Report 83-13 January 1983

DEVELOPMENT OF A COMPUTER-BASED TACTICAL TRAINING SYSTEM

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FOREWORD

This research and development was conducted within exploratory development task ZF63-522-001-013-03.02 (Computer-based Techniques for Training Tactical Knowledge). It was sponsored by the Office of the Chief of Naval Operations (OP-01) with support from the Defense Advanced Research Projects Agency (CTO).

This report describes the development and evaluation of a computer-based memorization system for training tactical action officers (TAOs). Ultimately, this system can be used within TAO training to evolve student models, computer tutors, and gaming techniques to facilitate the learning of declarative information. Details of some of the earlier work on this effort were documented in a previous report (NPRDC TN 81-8).

Results of this R&D are intended primarily for designers of computer-based instruction and the operational tactical training community.

JAMES F. KELLY, JR.
Commanding Officer

JAMES W. TWEEDDALE
Technical Director

SUMMARY

Problem

Increasing technological sophistication and continuing scarcities in the supply of qualified personnel have created a need for improved Navy training, particularly in the area of critical combat skills. Emerging computer technologies may offer potential benefits for Navy training. Although the military has been performing research in computer-assisted instruction (CAI) since 1968, very little work has been done using microcomputers. This is also true in regard to evaluating "intelligent" CAI systems for military training, even though several ideas associated with artificial intelligence (AI) offer promise for improved training. Microcomputer technologies, as well as recent developments in AI, need to be evaluated in applied settings.

Purpose

The research described herein is part of a 3-year developmental effort. The overall purpose is to evaluate microprocessors for Navy training in a context that permits the exploration of training techniques related to AI and cognitive science. The specific objectives are: (1) to create a usable tactical memorization training system, (2) to gain experience in the in situ development of stand-alone CAI systems for Navy training, (3) to explore gaming techniques to facilitate the acquisition of declarative information, and (4) to use this developmental situation to evolve student models and computer tutors.

Approach

Tactical action officer (TAO) training was selected as the domain for this research because a major segment of this training involves memorization of declarative information. Further, the Navy has a need to facilitate the acquisition and retention of this type of information.

A data base of facts involving Soviet platforms and weapons systems was compiled, represented as a semantic network, and implemented on a TERAK microcomputer. This microcomputer was installed at the Fleet Combat Training Center, Pacific (FCTCP) where TAO training is conducted. A series of games that permit drill and practice on information in the data base and audit trails that collect extensive information on student use of the game were developed. The primary advantage of this type of development is that the gaming software may be considered a separate entitity from the data base. These games can be run on any data base that can be represented as a semantic network. Three other data bases were developed to test this claim.

All developmental work was carried out in a school setting. There was extensive participation on the part of the students and instructors at FCTCP throughout the project. Ideas were discussed with the users before work was started, their input was used in compiling the data base, and one microprocessor was installed at the school with the very earliest on-line development. Informal feedback solicited from school personnel in the early stages resulted in many changes in the games.

Results

At this time, systems are installed at FCTCP and students are using the games on a regular basis. The games are designed to supplement the TAO course and students may use them or other study methods.

The games have been available to students from three TAO classes (N = 54). About half of these students have used the games and data have been collected primarily for formative evaluation. Measures of school-administered tests, computer audit trails, and attitude questionnaires were collected.

A number of changes were made in the interface for the system as a result of informal feedback and the questionnaire data. It became clear over time that the structure of the interface is a strong determinant of how much time students are willing to spend on the system. Although not all students chose to use the gaming system, those who did had positive feelings about it and preferred some games more than others. The instructors were enthusiastic and supportive of the research.

Conclusions

The gaming system developed can be used for tactical training and offers promise for additional development planned for the last year of the effort. In situ development facilitated the effort, provided new directions, and ensured user support. The work was generalized to other training domains with the development of additional data bases. Additionally, the flexibility of microprocessors for this kind of Navy training was demonstrated.

Future Direction

The gaming system is being transitioned into advanced development funding as a part of the Computer-based Educational Support System project.

CONTENTS

INTRODUCTION

Problem

There is a continuing need for improved Navy training, particularly for critical combat skills. As the technologies supporting weapons systems have become more sophisticated, the Navy has experienced a decline in trained personnel. Means are needed to train people quickly, effectively, and at low cost. Emerging technologies in combination with new and existing training methodologies need to be investigated in response to the training problem.

New developments in computer technologies, particularly microcomputer-based systems, offer potential benefits for training. These systems represent increased computational power in a smaller, portable configuration at lower cost. There is a need to evaluate such systems in applied settings to determine their advantages and disadvantages for computer-assisted instruction (CAI) in Navy training.

There is also a need to explore the applicability of training methodologies related to cognitive science and artificial intelligence (AI) for Navy computer-based systems. Intelligent CAI may offer the increased individualization required for the wide range of abilities people have in initial training and the automated tutor capabilities needed for refresher training outside of schools.

Background

The military has a history of interest in computer applications in training. Since 1968, researchers in all of the services have collected data from a wide variety of experimental programs. Their interests have focused on evaluations of particular CAI systems (e.g., Ford, Slough, & Hurlock, 1972; Hurlock & Slough, 1976), evaluations of training for particular communities (e.g., Kribs, 1976), cost effectiveness of CAI (Orlansky & String, 1979), and skills ranging from procedural (e.g., Fredericks & Hoover-Rice, 1977) to "hands-on" performance training (e.g., Trollip, 1977). These efforts have been primarily concerned with large, time-sharing systems or minicomputers.

The cost and training effectiveness of these experimental efforts has been questioned (Orlansky & String, 1979); however, this kind of research is needed to improve military training as well as to explore promising technological advances. There is a need, at this time, to evaluate stand-alone microprocessors for training and to determine the most appropriate training materials for this medium, the existence of any maintenance and user problems, and software development costs for these systems.

One of the few training efforts involving microcomputers was carried out at this Center by Kelly, Greitzer, and Hershman (1981), who investigated human performance in anti-air warfare threat analysis. An interactive air defense game was developed and presented on the computer screen. Research subjects played the game while the computer presented feedback and collected data. The researchers concluded that proficient performance was attained and that the game provides an effective vehicle for human performance research. The results demonstrated the flexibility and portability these systems offer for Navy training.

Purpose

The research described herein is part of a 3-year developmental effort. The overall purpose is to evaluate microprocessors for Navy training in a context that permits the

exploration of training techniques related to AI and cognitive science. The specific objectives are: (1) to create a usable tactical memorization training system, (2) to gain experience in the in situ development of stand-alone CAI systems for Navy training, (3) to explore gaming techniques to facilitate the acquisition of declarative information, and (4) to use this developmental situation to evolve student models and computer tutors.

APPROACH

Training Domain

Tactical action officer (TAO) training, which requires students to memorize a large body of facts related to hostile and friendly platforms and weapons systems, was selected as the subject matter area for the present research for two reasons: (1) it is a domain in which combat skills are crucial and (2) it appeared that results obtained might be useful for both initial and refresher training. The TAO is a multithreat evaluator and decision maker who must defend his ship with any or all of the weapons systems or platforms available to him. He must have a thorough knowledge of (1) the capabilities and limitations of hostile weapon platforms so that he can determine the existence and priority of a threat, and (2) the assets of his own ship and Navy to enable him to counter that threat quickly.

TAO training is conducted at the Fleet Combat Training Centers, Pacific and Atlantic (FCTCP and FCTCA), and at the Department Head Course at the Surface Warfare Officer School. Students must master information on enemy platforms, weapons systems, parameters of all weapons systems (e.g., range, speed, flight profile, guidance systems, etc.), electronic suites, and surveillance capabilities. They must master the same information for the U.S. Navy, plus theory on acoustic and electromagnetic propagation, theory on missile guidance system techniques, and, finally, tactics including such topics as rules of engagement. This demanding 6-week course consists of lectures and simulation exercises.

The information taught to TAOs is difficult to acquire and very difficult to maintain unless it is used continually. There is, therefore, a need to facilitate the initial acquisition of this material, as well as to provide some means for refresher training: A microprocessor-based training system with an automated tutor might be a good solution for both needs. Microcomputers can be installed easily at the school, in ships, or at dockside. Also, the automated tutor can supervise student interactions to provide feedback and direction.

Software Development

This effort involved the development of a software system with the UCSD PASCAL operating system on a small, stand-alone computer system. The software, which was designed to provide drill and practice through game playing with a data base of Soviet Navy platforms and weapons, has been implemented at FCTCP as part of the TAO training course.

The TERAK microcomputer,[1] an LSI-11-based dual floppy disk drive system with 32k word memory capability, was selected for the initial phase of this research. It includes a

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[1]Identification of the equipment is for documentation purposes only. It does not constitute endorsement by the Navy Department, since many similar microcomputers could serve the same purpose.

CRT display for the presentation of graphics and text in black and white. Eventually, the software implemented on the TERAK will be transferred to the PERQ system, which has 128k words of memory, a 24-megabyte Winchester disk, and high resolution graphics (1024x768). The PERQ will provide the memory capacity required for the development of student models and a more advanced automated tutor.

Data Base

A data base was developed of all Soviet threat information taught in the TAO course. This consists of a series of facts about Soviet platforms, weapons systems, and the parameters associated with both. Since the data base was compiled and is being maintained by instructors from the TAO school at FCTCP, it reflects the information being taught at the school at any given time.

The data base was structured as a semantic network and then entered into the system. The data in a semantic network consist of nodes that represent objects and links between those nodes that show relationships between the objects. For example, in the data base for this project, the two objects "ship" and "radar" are related by "has," allowing the system to record the fact that ships have radars. Beginning with the definition of all of the objects in the data base, a hierarachy is developed in which objects and their relationships are specifically defined. Figure 1 shows the definitions associated with the fact that "KYNDA has peel group." Figure 2 shows all of the information recorded about the KYNDA. A typical data base contains representations of several thousand such facts. Not all of the entries will be defined as objects. Some of them are attributes, such as "KYNDA speed 30 kts," where KYNDA is an object, speed is a relationship, and 30 kts is an attribute.

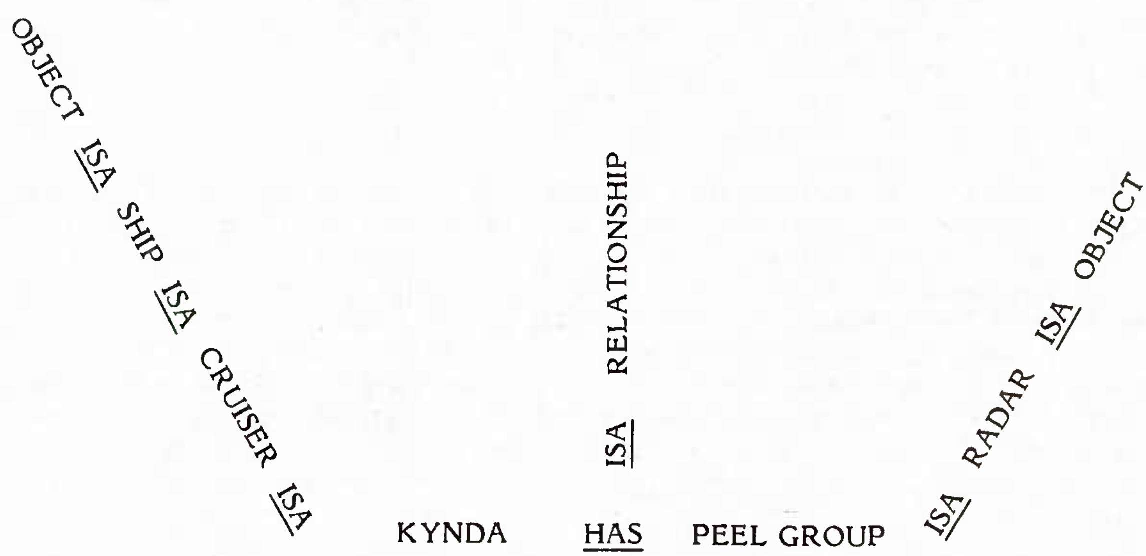

Figure 1. Sample semantic network triangle.

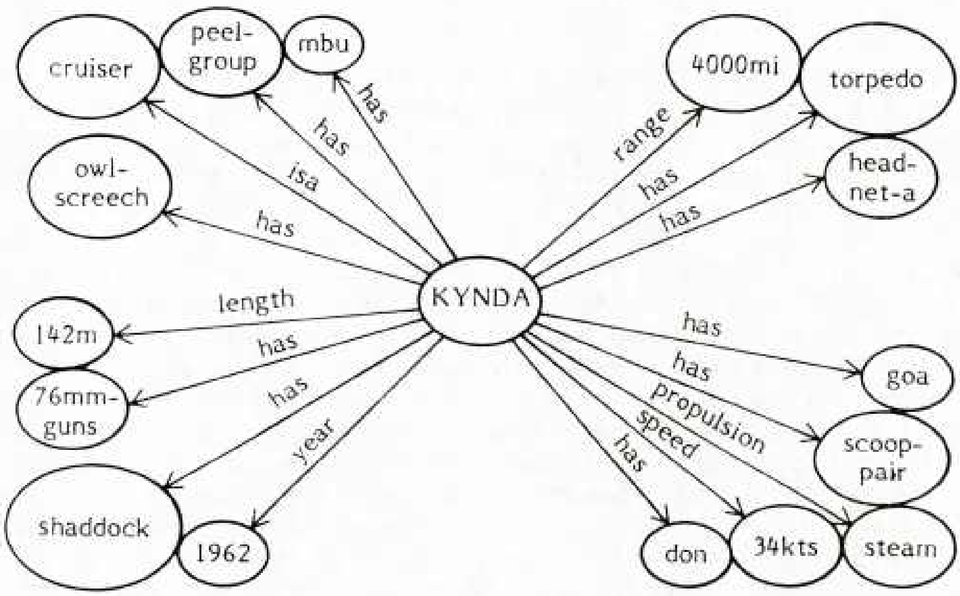

Figure 2. Sample semantic network node.

The data base also includes synonyms and quantifiers. Synonyms allow the same object to be referred to in multiple ways. A limited form of quantification is implemented so that the number of radars or other objects associated with some particular object can be represented.

Computer Games

Given this kind of representation of the data base, it is then possible for additional, independent software, or interpretive procedures, to interact with and manipulate the data base in an intelligent fashion. For example, the interpretive software can make inferences about the data base; it "knows" enough about the structure of the data to ask questions such as "What radars does the KYNDA carry?" The software in this system consists of a series of games that quiz the student about the data base. Since these games are separate from the data base, they will run on any data base that can be represented in the semantic network format just described. In quizzing the student, the gaming software draws items randomly from the data base and generates questions, examples, or graphics. Unlike previous computer-based training, these exercises are not specifically preprogrammed.

The following games are available:

1. Flash. The program quizzes the player about facts in the data base. Students may choose to have the questions presented in either the recall or recognition mode.

2. Twenty questions. The computer "thinks" of an item and the player must guess what it is by partitioning the data base. The student might ask, "Is the item carried on cruisers?" The computer will then respond with a true or false answer and the student can proceed with more questions.

3. Concentration. The student is presented with a list of items. He must match those items that are related by common characteristics.

4. Constraints. The student is required to narrow down a list of objects by knowing what they have in common. This is very much like the actual TAO task in that the TAO typically continues to receive bits of information until he can identify the threat. For example, if a certain type of radar emission is received, the TAO must know which platforms in his area could be sending that emission. Usually, reception of several more emissions are necessary to identify the specific threat.

5. Matrix. The student must fill in the answers to threat matrices chosen either by the instructor or himself. The matrix has column and row headings chosen from the data base (e.g., KYNDA and radar) and the student must fill in the boxes (e.g., peel group).

6. Show. The program presents a graphic representation of the data base. It is more of a reference function than a game. When the student enters "KYNDA," the system displays everthing it knows about that ship, as in Figure 2.

7. Picture quiz. This game presents graphic representations of ships in the data base. The student is supposed to identify the ships or their individual components.

The interface to the game system has been the focus of much effort in this project. The keyboard with the TERAK system has the standard alphanumeric character keys, plus several others dedicated to special functions in an attempt to facilitate the use of the interface. The student uses these special keys whenever possible, making typewritten entries only where necessary. There are horizontal- and vertical-arrow keys that move the cursor around the screen and that are used primarily for selecting responses. There are also "tell me," "hints," "quit," "select," and "help" keys, which are functional in all of the games.

Extensive use has been made of menus, or lists of options, for the system interface. The student selects from menus the game he wants to play, the category of the data base he wants to be quizzed on (e.g., missiles, any subcategories such as surface-to-surface missiles) and, in many cases, possible answers to questions. To use these menus, the student simply positions the cursor next to the desired response and presses "select."

Procedure

Audit trails were developed to collect information on all student interactions with the system. They recorded (1) the games played, (2) the data base categories selected, (3) the questions, hints, help, and answers generated by the system, (4) students' answers and options exercised to quit, and (5) time spent on the system.

All developmental work was carried out in situ; that is, in the school setting. There was extensive participation by FCTCP students and instructors from the beginning of the project. Ideas were discussed with the users before work was started; they compiled the data base; and, early in development, one TERAK was installed at the school. Because informal feedback was solicited throughout the development, changes were continually being made to the system.

Once the games were in reasonable working order, three more TERAKs were installed at the school for the students' use. The students participate in simulation exercises and receive lectures every day. At the end of the day, they study before going home. The TERAKs were available for those who wanted to use them to study, but no one was required to use them if they preferred other study methods. Students who used the systems were told that the development was still in the early stages and their critical comments were encouraged. The games were available to three classes of students (N = 54).

Audit trail data, school test scores, and attitude questionnaire responses were collected from all students. These data will be used in the future for the development of student models and the automated tutor, as well as for a formal evaluation of training effectiveness. The questionnaire data, in combination with comments solicited from students and instructors throughout the development, were used for formative evaluation.

Other data bases were also compiled and implemented to test the generalizability of the gaming system. These data bases contained facts related to South American geography and electronic warfare threat evaluation.

At this time, formative evaluation is continuing. Much of the primary efforts are directed toward converting the software to run on the PERQ system.

FINDINGS AND DISCUSSION

In Situ Development

In situ development of the tactical training system created an environment in which continuous and extensive input from users was provided to the system designers. From the conceptualization stages through implementation of computer-based materials at FCTCP, students and instructors were involved in each phase of the work. This differs markedly from the approach typically taken in developing CAI.

The iterative changes possible with in situ development seemed to be a better, more efficient approach for producing the end product. This form of development encouraged close interactions with potential system users during the critical early design stages and allowed the interaction to continue throughout the project. As a result, the end product reflects user needs, rather than researcher ideas of user needs. Also, since the user community participated in shaping the materials, there were involvement and support at the time of implementation for student testing.

The feedback received on the gaming system throughout its development ranged from very informal feedback from both students and instructors to responses on the attitude questionnaire administered to the three classes of students. This feedback resulted in major changes in the games, the game instructions, and, primarily, the system interface. These changes will be described in the following section.

Tactical Gaming System

The TAO course is conducted in a very high pressure environment since a massive amount of information must be mastered in 6 weeks. As a result, students are not willing to spend much time learning anything more than is required for the class. Thus, in the early stages of development, not very many students learned to use the computer-based system as a study aid. Rather, they would return to the reliable study methods (i.e.,

practicing with flash cards, devising threat matrices, and reviewing class notes) they had used before.

If the games were hard to understand, students ignored them. The students did not like a game called "browse," even after the interface had been simplified. The researchers had felt that this would be a very well-liked game because it appeared to be a valuable study tool. Apparently, however, students felt too much explanation was required before they could understand how to use the game. This was a normal reaction, because the students had not been presented with material that convinced them that the computer-based system was a superior study aid. They felt that, even if they were very familiar with how to use CAI, it was no better than the study methods they were using. The people who did use the gaming system had much different feelings about it; their attitudes will be described later.

The complaints made by students who used the system motivated many changes in the system interface. One very common complaint was that too many manipulations were required before one could begin studying. In the early stages of the devleopment, considerable use of the keyboard was required to move around the system. This was changed by (1) implementing menus wherever possible, and (2) designating special key functions (by labeling existing keys). Except for answers required for some of the questions, the student is required to do very little typing. Instead, he positions the cursor next to the desired option and presses the "select" button. In most cases, the student only has to select the game, the data base, and the categories before beginning to play the game.

Another common complaint was that the system was not very flexible in terms of the input it would accept. To eliminate this problem, a spelling corrector was developed and an extensive list of synonyms was put in the data base.

The items in this particular data base are subject to change and, although there were never more than one or two inaccuracies, students were very intolerant if there were any. As a result, a data base editor was developed for use by school personnel to update and change the data base rapidly.

The students did not appear to be very interested in anything not strictly designed to facilitate memorization of the facts needed for the school tests. The constraints game, which was most like a TAO task, was not rated as highly as were the other games. The idea for this game had been suggested by a fleet TAO, who believed that this kind of development was really needed and would be highly motivating to keep requisite skills up to date. It may be that this kind of game would be more suitable for those who have already been through the course to use aboard ship or in other refresher applications. Similarly, from talking to instructors and fleet TAOs, it was assumed that scoring the games would be a motivating feature because it would introduce a competitive element. However, the students felt quite differently; the majority felt that scoring was not necessary.

Ideas for new games were additional results of performing this work in situ. The picture quiz game, for example, resulted from one instructor's opinion that the ability to recognize a ship from its silhouette is related to a good working knowledge of the data base.

The instructions also had to be changed to suit student needs. Originally, a lengthy hard copy of system instructions, including instructions and objectives for each game, was placed beside each terminal. Just as with the interface, students did not want to be

bothered with anything they did not need to know. As a result, the instructions were shortened considerably and put on-line. Only the essential information was presented and then only at the time and location when needed. It was presented either as a prompt always on the screen or as a short sentence accessed by the "help" prompt.

The students who chose to use the system tended to be those who scored highest on the class tests and/or had some experience with computers before the TAO class. In any case, they were clearly comfortable taking the time to learn to use the system. Once these students were working on the system, they tended to continue using it several hours a day after class lectures. They said that they liked the system for the following kinds of reasons:

- It is good for asking questions you would not ask yourself.
- It is faster than self-study.
- You can cover more information this way.
- It points out your weak areas.

These students were asked to rate the games on a scale that included the following points: very effective, effective, somewhat effective, ineffective, very ineffective, and did not play. Most of the students rated the games "effective."

Although the data collected by the audit trails have not yet been evaluated, the implementation of audit trails for student runs has provided some important information. For example, an excessive amount of data were specified in terms of what could realistically be used. This aspect of the data collection effort had no effect on students. While they were aware that the system was keeping records of their inputs, the process was not intrusive. Data collected in this manner will eventually be used for developing student models and as input for the evaluation of training effectiveness.

Microprocessors for Navy Training

The microprocessor system used in this effort was very effective for the work done to this point in time. The physical configuration of such desk-top systems makes them highly portable. As they are small and need only a few plugs for connections, they are very easy to move for repair or relocation.

Given the eventual goal of developing student models and a sophisticated automated tutor, the TERAK system has reached the limits of its memory capabilities for this project. It did, however, prove very capable of handling a variety of features directly related to user acceptance (e.g., the data base editor, the spelling corrector, etc.). These features were additions to what was already a very unique and advantageous approach to computer-based training; that is, using a semantic network to represent the data base. Thus, a small stand-alone microprocessor system has been shown to be capable of providing fairly sophisticated computer-based training that is considered useful by the Navy users.

Semantic Networks

The major advantages of using semantic networks for computer-based instruction are that (1) the degree of individualization provided is greater than that which the traditional approach would provide in proportion to the programming required, and (2) the interpretive procedures developed can be generalized to any other data base that can be represented as a semantic network.

The semantic network structures the data base so that the gaming software can draw items from the data base as needed. This permits students to progress through drill and practice on the declarative information whenever and as often as they wish, and lets them omit any questions or sequences in which they are not interested. The standard approach to development of computer-based instruction does not easily provide this kind of flexibility.

The implementation of additional data bases performed as part of this effort demonstrated the generalizability of the gaming software. Once the data bases were compiled, implementation consisted of typing the entries into the system. The result was that, with the exception of games using graphics, a new series of games was easily and quickly created for each new subject area.

CONCLUSIONS

The research described in this report focused on the combined elements of in situ development of computer-based training, gaming for memorization of declarative information, methodologies related to intelligent computer-assisted instruction, microcomputer systems for training, and development of computer-based drill and practice materials to supplement (rather than replace) traditional forms of Navy training. Although the evaluation of the impact of these elements on training effectiveness has not yet been completed, some comments can be made about what has been learned over the past 2½ years of development:

1. The system that was designed is useful for memorizing declarative information. Once students start using the system, they continue to use it and report that it is an effective study aid.

2. Gaming seems to be a reasonable approach for drill and practice of this kind of information. To evaluate the effect of games fully will require the collection of some specific information about what makes the games interesting for this particular group of students. Early information, for example, suggested that competition is not a necessary element.

3. The use of the semantic network permitted increased individualization in that it provided enough flexibility to serve the wide range of abilities brought to training. Additionally, once the software was developed for the semantic network and the games, it was readily generalized to other data bases.

4. Microprocessors offer several advantages over larger systems for Navy training. They are portable and easily repaired. Additionally, the users were able to take full responsibility for running students and maintaining the data base.

5. In situ development was convenient for the researchers and had several advantages for the users. The resultant end product is one that reflects user needs and, therefore, has their support.

FUTURE DIRECTION

The gaming system is being transitioned into advanced development funding as part of the Computer-based Educational Support System project.

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Commanding Officer, Fleet Combat Training Center, Atlantic
Commanding Officer, Fleet Combat Training Center, Pacific
Commanding Officer, Naval Training Equipment Center (Technical Library)
Director, Naval Education and Training Program Development Center Detachment, Great Lakes
Director, Naval Education and Training Program Development Center Detachment, Memphis
Director, Training Analysis and Evaluation Group (TAEG)
Officer in Charge, Central Test Site for Personnel and Training Evaluation Program
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Commander, Air Force Human Resources Laboratory, Brooks Air Force Base (Scientific and Technical Information Office)
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